

The Characterization of the Selected Materials for Space Shuttle

Hae Soo Kim

NE-L2-C, Kennedy Space Center, NASA, FL 32899, U.S.A

The harsh conditions to which the Space Shuttles are exposed during flight required the development and use of many unique materials. These materials were specially designed to withstand extreme temperatures, in some cases over 1600 °C, while other material must withstand the cryogenic conditions of – 253 °C, and others must operate while under extreme loads. All of these materials must not only operate in the harsh condition but they must be light weight as well. The Space Shuttle is composed of three major components when configured for launch, Figure 1; the Shuttle, solid rocket boosters, and external tank (ET). The different heat shields of the Shuttle make up the thermal protection system (TPS); this system consists of many different types of components designed to operate on various parts of the vehicle. The body of the Shuttle and ET are composed mainly of aluminum alloy and graphite epoxy.

The TPS consists of reinforced carbon-carbon (RCC) used on the wing leading edges and nose cap areas while the upper forward fuselage areas, the entire underside of the Shuttle, the Orbiter maneuvering system, and reaction control system utilize black high temperature reusable surface insulation (HRSI) tiles, Figure 2. Other areas of the Orbiter are protected by fibrous refractory composite insulation (FRCI) tiles. Areas where the temperature stays below 649 °C, such as the forward fuselage, mid-fuselage, aft fuselage, vertical tail, and upper wing, are protected by other material such as, white low temperature reusable surface insulation (LRSI) tiles, advanced flexible reusable surface insulation (AFRSI) blankets, and felt reusable surface insulation (FRSI) white blankets.

The RCC is a pyrolyzed laminated carbon with the outer surface converted to silicon carbide to prevent oxidation. The HRSI tiles are made of a low-density, high purity silica 99.8-percent amorphous fiber insulation that is made rigid by ceramic bonding resulting in 90-percent void and 10-percent materials. The RCC and HRSI are used in areas where the temperature rises above 1260 °C.

The FRCI tiles are high strength tiles derived by adding alumina-borosilicate fiber to the pure silica tile slurry that welds the micron-sizes fibers of pure silica into a rigid structure during sintering. The FRCI is composed of 20-percent alumina-borosilicate fibers and 80-percent silica fibers, and provided improved strength, durability and resistance to coating cracking and weight reduction than HRSI.

The LRSI tiles composed of the 99.8-percent pure silica fibers while the AFRSI consists of low-density fibrous silica batting that is made of high purity silica and 99.8-percent amorphous silica fibers. The FRSI, used on the upper payload bay doors and fuselage, consists of glass fibers, bonded directly to the orbiter by room temperature vulcanizing (RTV) silicon-adhesives.

Additional materials are used in other areas such as thermal panes for the windows, thermal barriers, and gap filler around operable penetrations. The external tank thermal protection system (ET TPS) consists of sprayed-on foam insulation and remolded ablator materials. The system also includes the use of phenolic thermal insulator.

The use of such a wide range of materials requires close attention to possible damage caused by debris. Post flight inspection of the TPS includes detailed analyses of any debris found on damaged parts. The results of these analyses are used to help determine the source of the debris to help prevent future damage.

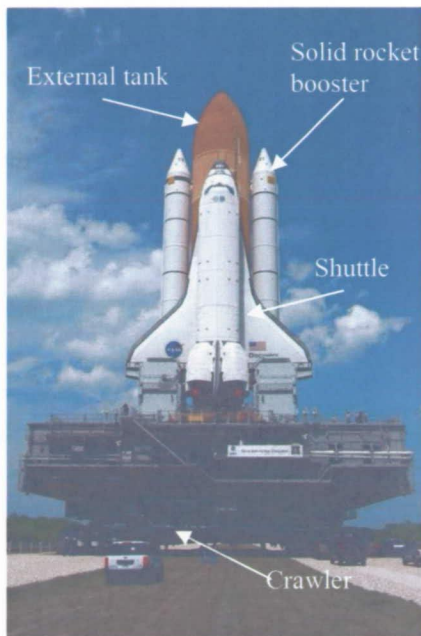


Figure 1. Space Shuttle

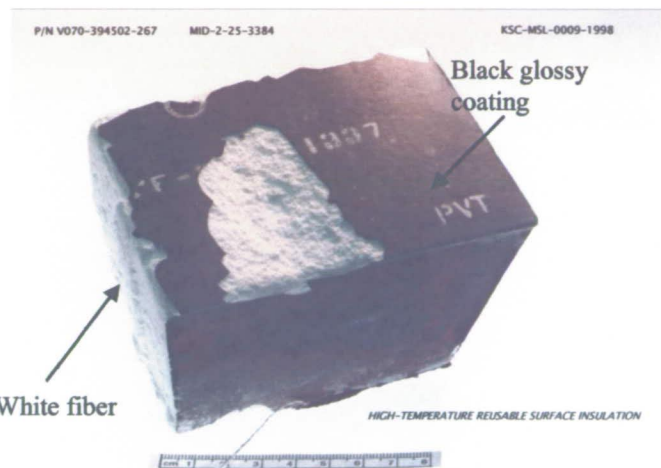


Figure 2. High temperature reusable surface insulation